ENCOUNTER RATES OF WHALES AROUND THE ANTARCTIC PENINSULA WITH SPECIAL REFERENCE TO HUMPBACK WHALES, *MEGAPTERA NOVAEANGLIAE*, IN THE GERLACHE STRAIT: 1997/98 TO 1999/2000

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During the austral summers of 1997/98 to 1999/00, the Projeto Baleias/Brazilian Antarctic Programme conducted ship-based surveys of cetacean distribution and sighting frequencies in the Gerlache Strait and around the South Shetland Islands - Antarctic Peninsula region. These surveys included humpback whales (*Megaptera novaeangliae*), for which biopsy sampling and photo-identification were also undertaken. Data gathered during the 1997/98 summer season indicate that the humpback whale is the most commonly seen cetacean in the surveyed areas. Its high encounter rate (0.32 whale/nautical mile) was followed by minke whales, *Balaenoptera* spp. (0.14 whale/nautical mile), killer whale, *Orcinus orca* (0.03 whale/nautical mile), sei whale, *B. borealis* (0.01 whale/nautical mile) and other unidentified animals (0.004 whale/nautical mile). The highest encounter rate for humpback whales was in the Gerlache Strait (0.42 whale/nautical mile; CV = 55.5%), where encounter rates were obtained from six surveys (1997/98), three surveys (98/99) and two surveys (99/00), allowing for inter-annual comparisons. Although a decrease in the mean encounter rate of humpback whales in the Gerlache Strait was observed over the period, Anova and Kruskal-Wallis tests showed no statistical significance. A longer time series would be necessary to draw conclusions with respect to temporal trends. ❐ *Humpback whale, cetaceans, population density, Antarctic Peninsula, Gerlache Strait.*

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Historic and current information on the abundance of southern humpback whales, *Megaptera novaeangliae*, is scarce, though catch data suggest that the species was abundant prior to the modern whaling era (Gambell, 1973a; Mizroch, 1984). During the 20th century, humpback whales were extensively hunted in the Southern Hemisphere (Tønnessen & Johnsen, 1982). High catch rates reduced the population to only a few percent of its estimated original size (e.g. Gambell, 1973b, 1974; Breiwick & Braham, 1984; Mizroch, 1984). However, some population data were gathered during this period (e.g. Mackintosh, 1942; 1965; 1972; Dawbin, 1964; 1966; Chittleborough, 1965), whereas information after the cessation of commercial whaling is sparse. The necessity to comprehensively assess the current status of humpback whales in the Southern Hemisphere has led the International Whaling Commission (IWC) to recommend multilateral studies in the species' breeding and feeding grounds. Several cruises have been conducted in the Southern Ocean (e.g. IWC/IDCR, Japanese scouting vessel surveys), but it remains important that any surveys conducted in this area include a cetacean component. In the 1994/95 austral summer we participated in the Brazilian Antarctic Programme (PROANTAR), created in

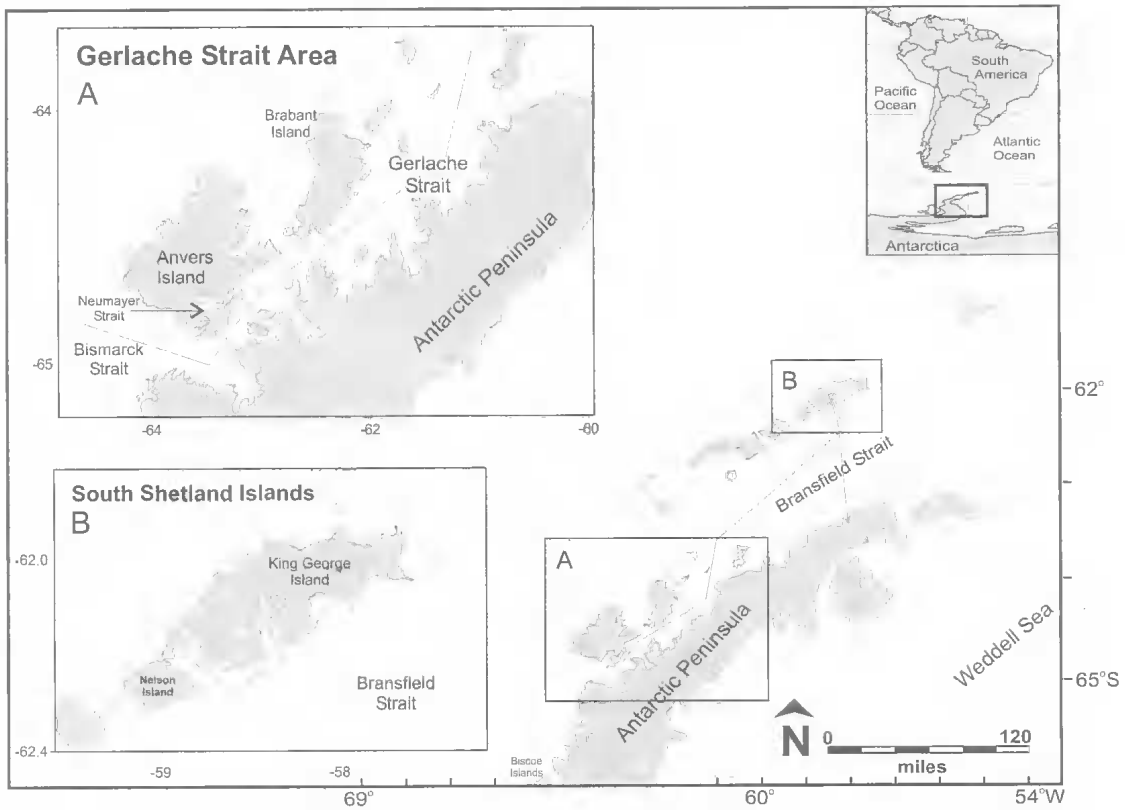

FIG. 1. Study area around Antarctic Peninsula. Transect lines for each surveyed region are shown in detail.

1982 within the aims and policies of the Antarctic Treaty. During the first year of the cetacean component within PROANTAR (herein referred as Projeto Baleias/PROANTAR), we evaluated the suitability of using a ship as a platform of opportunity to study cetaceans in the Antarctic. Our major objective was defined as providing information to improve assessment of humpback whales in the Southern Hemisphere (Secchi et al., 1999). In the summer of 1997/98 we began to: 1) photo-identify humpback whales around the South Shetland Islands and the Antarctic Peninsula (for comparison with international catalogues); 2) biopsy humpback whales from the same areas for DNA and pollution analyses; 3) estimate cetacean encounter rates in these areas; and 4) record all cetacean sightings.

This paper compares the encounter rates of humpback whales in the Gerlache Strait in the summers of 1997/98 to 1999/2000. For 1997/98 we also compared the encounter rates of humpback whales with other areas around the South Shetland Islands and with those of other cetaceans.

MATERIAL AND METHODS

During the austral summers of 1997/98 to 1999/2000, the Projeto Baleias/PROANTAR conducted ship surveys to determine cetacean distribution and encounter rate estimates in the Gerlache Strait and around the South Shetland Islands - Antarctic Peninsula region (the boundary between IWC management areas I and II; see Donovan, 1991) (Fig. 1). Special attention was paid to photo-identification (see Dalla Rosa et al., 2001) and biopsy sampling of humpback whales. Surveys were conducted onboard the 75m Oceanographic and Supply Vessel (NApOc) 'Ary Rongel'. Although most survey transects were conditioned to the navigation schedule of Projeto Baleias/PROANTAR, dedicated cetacean surveys were performed in the Gerlache Strait. In this area, whale encounter rates were obtained from six (1997/98), three (98/99) and two transects (99/00), allowing for inter-annual comparisons. For each intra-annual survey the mean encounter rate and its respective variation was estimated using each transect as a sample. Sighting per unit of effort (SPUE), as the rate of

sighted whales per nautical mile surveyed, was used as a simple index of density. Since it is known that the detection probability varies among species (Kasamatsu et al., 1996), the encounter rates of different species were not directly compared in the statistical analysis. For the 1997/98 summer, encounter rates were compared between several surveyed areas.

Observation platforms were the exterior wings of the bridge, ~14m above sea level, except during unfavourable weather conditions (sea state above Beaufort 4, low visibility) when the observers used the bridge. A full search for cetaceans was conducted whenever the vessel was under way and weather was favourable. The number of observers varied from one to three (mostly two), who generally rotated every 30 minutes at each wing of the ship. Each person worked for 90 minutes and rested for 30 minutes. Each observer covered one side of the vessel's trackline forward of the beam (90° quadrant). Three observers were used only when one observer had no previous experience. In such cases the data recorder helped the least experienced observer. Data collected for each sighting included: species (minke whales were not distinguished to form), number of whales, miles navigated, position, date, time and weather and sea condition. Ship speed varied from 10-12 knots, depending on the number of growlers and icebergs in the vicinity. Most surveys followed a 'passing mode' method with the exception being the 1997/98 survey in the Gerlache Strait, which followed a 'closing mode' on occasions when photo-identification was conducted simultaneously. In these cases one observer stayed on the bridge to record any whales passed by the ship. Whales were searched for using the naked eye and 7x50 binoculars. Binoculars were also used to identify species and numbers of individuals. Only data obtained during searching effort were considered in the analysis (i.e. crew and researcher sightings made 'off effort' were not included). Search effort was restricted to sea conditions ranging from Beaufort scale 0-4 (mostly <3) to reduce effects on sighting probability. We consider that this variable did not strongly influence encounter rate estimates. Visibility was generally sufficient to allow reliable sightings in terms of species identification and estimation of group size up to a distance of two nautical miles (for large whales). Although visibility categories tend to be subjective (as Beaufort sometimes is) and may vary among observers, its final classification was defined on a common sense basis. Completely clear sky was considered as an excellent visibility condition. When fog slightly limited observer's sight of the horizon, visibility was classified as moderate. An approximate control of the observer's limit of visibility was obtained by using the ship's radar to read distances from the ship to growlers and icebergs.

Anova and Kruskal-Wallis tests were applied to test for differences between humpback whale encounter rates in the Gerlache Strait for the three periods.

RESULTS

WHALE ENCOUNTER RATES AROUND THE ANTARCTIC PENINSULA. Whale encounter rates for the summer of 1997/98 were highest in the Gerlache and Bransfield Straits (0.62 whale/nm) and lowest around King George Island (0.19 whale/nm) (Table 1). Estimated mean encounter rates showed humpback whale to be the most commonly seen species in the surveyed areas (0.32 whale/nautical mile), followed by minke whales, *Balaenoptera acutorostrata* + *B. bonaerensis* (0.14 whale/nautical mile), killer whales, *Orcinus orca* (0.03 whale/nautical mile), sei whales, *B. borealis* (0.01 whale/nautical mile), and other unidentified animals (0.004 whale/nautical mile). The few sightings of southern right whales, *Eubalaena australis*, and fin whales, *B. physalus*, occurred outside the surveyed areas or during off-effort times. Our results show a high concentration of humpback whales in protected coastal waters to the west of the Antarctic Peninsula, making them the most frequently sighted species in the area. This agrees with the long-term serial data presented by Kasamatsu et al., (1996), which also indicated the highest encounter rate of humpback whales to be west of the Antarctic Peninsula, between 60°W and 80°W. These authors found the latitudinal peak in encounter rates to be between 62°S and 66°S, which also matches our findings. The northern and southern boundaries of the Gerlache Strait (ca. 63°45'S to 65°00'S), the area where we recorded the highest encounter rates for humpback whales, are within those limits. This is intermediate to the latitudinal peaks for blue whales, which are found further south (≥66°S), and fin whales, found further north (≤58°S) (Kasamatsu et al., 1996).

Minke whales produced the second highest encounter rate (0.14 whale/nautical mile; CV = 122.2%) in the region. A high coefficient of variation (calculated from the density values recorded for all surveyed areas) is attributed to

TABLE 1. Summarised whale densities around the Antarctic Peninsula during the Brazilian Antarctic Survey XVI (summer 1997/98).

Area	Species	No. of whales	N miles surveyed	Sighting frequency
Gerlache Strait	humpback	153		0.49
	minke	16		0.05
	killer	24		0.08
	Total	193	312.2	0.62
King George Island	humpback	26		0.18
	minke	1		0.01
	Total	27	146.5	0.19
Bismarck Strait	humpback	13		0.39
	minke	2		0.06
	Total	15	33.4	0.45
Neumayer Passage	humpback	0		0
	minke	6		0.32
	Total	6	19.0	0.32
Biscoe Islands	humpback	9		0.34
	minke	0		0
	unidentified	1		0.04
	Total	10	26.5	0.38
Bransfield Strait	humpback	48		0.21
	minke	86		0.37
	sei	6		0.03
	unidentified	2		0.01
	Total	142	229.8	0.62
General	humpback	249		0.32
	minke	111		0.14
	sei	6		0.01
	killer	24		0.03
	unidentified	3		0.004
	Total	393	767.4	0.51
Average and (C.V.)	humpback			0.27 (65.1%)
	minke			0.14 (122.2%)
	Total			0.43 (39.5%)

the aggregative behaviour of the species. Single minke whales have been observed in some areas (e.g. Neumayer and Gerlache Straits) whilst groups of tens of individuals were seen in others (e.g. Bransfield Strait). Although it is not recommended to make direct comparisons of encounter rates of different species, because the search half-width varies between species (mostly when they are different in size and behaviour, Kasamatsu et al., 1996), in some areas encounter rates were higher for minke whales than for humpback whales (e.g. Neumayer and Bransfield Straits). Considering that minke whales have a much lower value of search half-width than humpback whales (see Kasamatsu et al., 1996) it is suggested that the former have a much higher relative density in those areas. A high sighting frequency for minke whales was also observed on the eastern side of the Antarctic Peninsula, where humpback whales were uncommon (Projeto Baleias/PROANTAR, unpubl. data). In the Gerlache and Bismarck Straits and near the Biscoe and King George Islands, minke whales were comparatively rare while humpback whales presented high encounter rates. The Gerlache and Bismarck Straits are adjacent to areas of high minke whale encounter rates, leading us to hypothesise that the two species may avoid ecological competition in the area, but further investigation is recommended. Latitudinal habitat segregation (or separation) between some baleen whales and toothed whales in the Antarctic has been suggested as an evolving adaptation to reduce competition for food (Kasamatsu & Joyce, 1995; Kasamatsu et al., 1996).

Sighting frequency of sei whales was low in the study area. Most sighting records during the Projeto Baleias/PROANTAR surveys occurred in the Drake Passage, north of the Antarctic Peninsula (Dalla Rosa et al., 1996; Projeto Baleias/PROANTAR, unpubl. data). Kasamatsu et al. (1996) also found that sei whale distribution was more restricted than that of other species and that the distribution in the Southern Ocean seems to be limited to warmer northern Antarctic waters (see also Kasamatsu et al., 1988). Mackintosh (1965) suggested that sei whales prefer warmer waters than fin and blue whales.

The lack of sightings of fin whales in sheltered areas around the Antarctic Peninsula conforms with previous studies. During the IWC/IDCR cruises from 1978/79 to 1983/84 nearly 70% of the sightings of this species were made in waters > 60 miles from the pack ice, with relatively large concentrations around the coordinates 58°S and 58°W, in the Drake Passage (see Kasamatsu et al.,1988). Kasamatsu et al. (1996) report a high concentration of fin whales between 40°W and 60°W and 54°S and 58°S. The species has frequently been observed within these coordinates when the Brazilian ship sailed from the South Shetlands to Elephant Island and from the latter to South America (Projeto Baleias/PROANTAR, unpubl. data). Armstrong et al. (1998) witnessed several groups feeding ~35 miles NE of Elephant Island (ca. 60°46'S 55°25'W) in February, 1997. These records suggest that the waters around

TABLE 2. Cetacean encounter rates (animals/nautical mile surveyed) in the Gerlache Strait (ca. 63°44'S 61°07'W to 64°59'S 63°23'W), Antarctic Peninsula.

	No. of cetaceans	Humpback	Minke	Killer	Miles surveyed	Beaufort	Observers	Visibility	Date	Humpback Enc. rate	Minke Enc. rate	Killer Enc. rate
1997/98												
Sample 1	16	15	0	0	51	1	1 to 3	good	25/01/98	0.29	0	0
Sample 2	19	19	0	0	21.5	1 to 3	3	good	27/01/98	0.88	0	0
Sample 3	45	42	0	0	69	1	3	good	03/02/98	0.61	0	0
Sample 4	29	28	1	0	74	1 to 4	3	moderate	04/02/98	0.38	0.014	0
Sample 5	26	11	9	6	38.1	3	3	good	07/03/98	0.29	0.24	0.16
Sample 6	59	38	3	18	58.6	1 to 3	2 to 3	good	08/03/98	0.65	0.05	0.31
Average (CV%)										0.52 (46%)	0.05 (54%)	0.08 (60%)
1998/99												
Sample 1	61	31	9	18	58.8	1 to 2	2	good/ moderate	27/01/99	0.53	0.15	0.31
Sample 2	10	8	2	0	29.7	1	2	good	29/01/99	0.27	0.07	0
Sample 3	44	26	17	0	66.5	0 to 1	2	excellent	01/02/99	0.39	0.25	0
Average (CV%)										0.40 (33%)	0.16 (58%)	0.10 (173%)
1999/00												
Sample 1	31	6	8	17	91.8	2	2	good	13/12/99	0.07	0.09	0.19
Sample 2	54	18	19	11	82.6	1 to 2	2	good	9/01/00	0.22	0.23	0.13
Average (CV%)										0.15 (73%)	0.16 (62%)	0.16 (27%)

Elephant Island are important concentration areas for fin whales.

The absence of blue whales in the survey area also conforms with previous studies. Kasamatsu et al. (1996) demonstrated a gap in the distribution of blue whales between 40°W and 60°W in the South Atlantic sector of the Antarctic (see also Kato et al., 1995).

INTER-ANNUAL COMPARISONS OF HUMPBACK WHALE DENSITIES IN THE GERLACHE STRAIT. Effort and whale encounter rates in the Gerlache Strait during the 1997/98 to 1999/2000 austral summers are presented in Table 2. Humpback whales presented a high encounter rate (mean estimated for the three surveys = 0.42 whale/nm; CV = 55.5%). This is about twice the estimates reported by Stone & Hamner (1988) for the same area. This difference may have arisen from temporal variation both within and between years in the humpback whale density in this area. Within-season differences in density may be related to timing of migration (see Fig. 2 and related discussion). Our surveys covered the area from early December to early March, with most of the effort concentrated in January and February while Stone & Hamner (1988) surveyed from 2 to 20 April, near the end of the feeding season. However, inter-annual variation may also explain the difference in density between the two studies in the Gerlache Strait, and may be related to temporal changes in prey density.

The apparent decrease in mean encounter rate of humpback whales observed over the three years (see Table 2) is not statistically significant [Anova: $F(2.8) = 2.41$; $p = 0.085$ and Kruskal-Wallis $H(2, N=11) = 4.93$; $p = 0.151$)]. A previous comparison between the first two periods, using t-statistics (Montogomery, 1984) through a randomisation test (Good, 1994), also displayed no statistical significance (Dalla Rosa et al., 1999). It would be reasonable to suppose that variation in the availability of prey (i.e. krill, *Euphausia superba*) could influence encounter rates of humpback whales. A gradual decrease in food availability may force whales to move to other areas. According to Brieley et al. (1999) and Hewitt & Demer (in press), the krill biomass around Elephant Island oscillates, varying from high to low within periods of about three to four

years. We suggest that the expected biomass should have reached low levels in summer 1999/2000 after a gradual decrease from the previous seasons. While these estimates are for the Elephant Island area, it is believed that these krill densities are representative of those throughout a much larger area of the Antarctic Peninsula region (Roger Hewitt, pers. comm.) (see Siegel & Loeb, 1995; Brieley et al., 1999 for supporting arguments). We could therefore expect a low encounter rate in this area for 1999/2000. However, our data showed a non-significant difference between study years. This suggests that models predicting oscillations in krill biomass may not be useful for predicting trends in whale densities, at least on a short-term basis. Obtaining more data through medium to long-term surveys in this area would enable monitoring of temporal trends in humpback whale densities. Simultaneous studies correlating these trends with environmental variables and krill biomass may elucidate inter-annual changes in humpback whale encounter rates.

MONTHLY VARIATION OF HUMPBACK WHALE DENSITY IN THE GERLACHE STRAIT. Encounter rates of humpback whales in the Gerlache Strait by half-month period (Fig. 2) are a combination of values obtained from different years and expeditions (since no significant difference was found in the inter-annual comparisons of humpback whale density estimates). The trend indicates a peak in density from late January to early March. This differs slightly from the results presented by Kasamatsu et al. (1996) who combined data from the entire Antarctic region. Those authors found a peak in humpback whale encounter rates in early January with a steady decrease through February and attributed this pattern to the segregation in the migration of populations described by Dawbin (1966). This variation might be attributed to different spatial and temporal scales between the sources of data. However, the high encounter rate for March and the relatively high encounter rate found in April by Stone & Hamner (1988) suggest that humpback whales remain in the Gerlache Strait as long as mid autumn. We attribute this relatively high density during autumn to the favourable conditions that the species may encounter in the Gerlache Strait; a narrow corridor, between Brabante and Anvers Islands and the Antarctic Peninsula, possibly providing both shelter and abundant krill. Zooplankton samples collected around the Antarctic Peninsula resulted in highest krill densities in the Gerlache

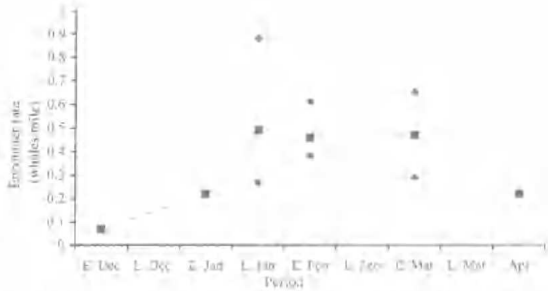

FIG. 2. Seasonal change in the encounter rates of humpback whales in the Gerlache Strait - Antarctic Peninsula, by half-month period from early December to April. Rates are averages from pooled data obtained in the three surveys. Dots represent maximum and minimum values for the period. The value for April taken from Stone & Hamner (1988). (E = early and L = late).

and Bransfield Straits (5717 ind/1000m^3 and 5723 ind/1000m^3, respectively). Montú et al., (1994) reported decreased concentrations of krill from about 830ind/1000m^3 to 16ind/1000m^3 as the distance from those areas increased. High concentrations of phytoplankton are also commonly observed in the area (El-Sayed, 1968; Montú et al., 1995). Loescher et al. (1997) and Bathmann et al. (1997) mention the occurrence of a seasonal input of nutrients and minerals (e.g. Fe) which coincides with blooms of phytoplankton observed in the spring. The oceanographic conditions together with local productivity of phyto and zooplankton may also explain the relatively high densities of humpback whales observed in the Gerlache Strait.

CONCLUSION

High densities of cetaceans (mainly humpback whales) have been observed in the Gerlache Strait. The area is a narrow corridor (~5-8 miles wide) with relatively calm waters, facilitating reliable observation. Such factors make it a strategic area for further integrated surveys. It may also be useful as a reference for comparing results obtained from ecological studies with the surroundings. Medium to long-term surveys in the area would allow temporal trends in whale densities to be monitored. Trends in whale density and distribution could be evaluated according to the density and distribution patterns of their prey (e.g. years of low krill biomass would be interesting to investigate if predators move to other areas or feed on different prey). Given the high concentration and accessibility of humpback whales in the Gerlache Strait, we

consider the area also appropriate for conducting long term photo-identification and genetic studies, potentially providing important information on site fidelity and migration, and genetic variability both within/between years and within/between areas. Such multidisciplinary studies would provide a valuable contribution to our knowledge of the ecology of the humpback whale in the Antarctic.

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LITERATURE CITED

ARMSTRONG, W.A., CURRY, B.E. & HEWITT, R.P. 1998. Fin whales (*Balaenoptera physalus*) feeding behaviour in Antarctic waters: herding and concentration of krill. Abstracts of the World Marine Mammals Conference, Monaco, 20-24 January, 1998.

BATHMANN, U.V., SCHAREK, R., KLAAS, C., DUBISCHAR, C. D. & SMETACEK, V. 1997. Spring development of phytoplankton biomass and composition in major water masses of the Atlantic sector of the Southern Ocean. Deep Sea Research 44(1-2): 51–67.

BREIWICK, J.M. & BRAHAM, H.W. (eds) 1984. The status of endangered whales. Marine Fisheries Review 46(4):15-44.

BRIERLEY, A.S., DEMER, D.A., WATKINS, J.L. & HEIWITT, R.P. 1999. Concordance of interannual fluctuations in acoustically estimated densities of Antarctic krill around South Georgia and Elephant Island: biological evidence of same-year teleconnections across the Scotia Sea. Marine Biology 134: 675-681.

CHITTLEBOROUGH, R.G. 1965. Dynamics of two populations of the humpback whale, *Megaptera novaeangliae* (Borowski). Australian Journal of Marine and Freshwater Research 16: 33-128.

DALLA ROSA, L., SECCHI, E.R., ZERBINI, A.N. & MOLLER, L.M. 1996. Cetacean sightings in western South Atlantic and Antarctic Oceans. Abstracts of the 7th Reunion de Trabajos de Especialistas en Mamiferos Acuaticos de America del Sur, Viña del Mar, 22-25 October, 1996.

DALLA ROSA, L., SECCHI, E.R., KINAS, P.G., SANTOS, M.C.O., ZERBINI, A.N. & BASSOI, M. 1999. Photo-identification and density estimation of humpback whales in Antarctic waters. Abstracts of the 13th Biennial Conference on the Biology of Marine Mammals, Maui, 28 November - 03 December, 1999.

DALLA ROSA, L., SECCHI, E.R., KINAS, P.G., SANTOS, M.C.O., MARTINS, M.B., ZERBINI, A.N. & BETHLEM, C.B.P. 2001. Photo-identification of humpback whales, *Megaptera novaeangliae*, off the Antarctic Peninsula from 1997/98 to 1999/2000. Memoirs of the Queensland Museum 47(2): 555-561.

DAWBIN, W.H. 1964. Movements of humpback whales marked in the southwest Pacific Ocean 1952 to 1962. Norsk Hvalfangstid 53(3): 68-78.

1966. The seasonal migratory cycle of humpback whales. Pp. 145-170. In Norris K.S. (ed.) Whales, dolphins and porpoises. (University of California Press: Berkeley).

DONOVAN, G.P. 1991. A review of the IWC stock boundaries. Reports of the International Whaling Commission (Special Issue 13): 39-68.

EL-SAYED S.Z. 1968. On the productivity of the Southwest Atlantic Ocean and the waters west of the Antarctic Peninsula. Antarctic Research Series 11: 15-47.

GAMBELL, R. 1973a. Sustainable yields: how whales survive. Pp. 193-202. In Calder, N. (ed.) Nature in the round. (Weindenfield and Nicolson: London).

1973b. Some effects of exploitation on reproduction in whales. Journal of Reproduction and Fertility, Supplement 19: 533-553.

1974. The unendangered whale. Nature 250: 454-455.

GOOD, P. 1994. Permutation tests: a practical guide to resampling methods for testing hypothesis. (Springer-Verlag: New York).

HEWITT, R. & DEMER, D. In press. AMLR program: temporal and spatial variability of Antarctic krill density in the vicinity of South Shetland Islands as estimated from acoustic surveys. U.S. Antarctic Journal.

KASAMATSU, F., HEMBREE, D., JOYCE, G., TSUNODA, L., ROWLETT, R. & NAKANO, T. 1988. Distribution of cetacean sightings in the Antarctic: results obtained from the IWC/IDCR

minke whale assessment cruises 1978/79 to 1983/84. Reports of the International Whaling Commission 38: 449-487.

KASAMATSU, F. & JOYCE, G. 1995. Current status of Odontocetes in the Antarctic. Antarctic Science 7(4): 365-79.

KASAMATSU, F., JOYCE, G., ENSOR, P. & MERMOZ, J. 1996. Current occurrence of baleen whales in Antarctic waters. Reports of the International Whaling Commission 46: 293-304.

KATO, H., MIYASHITA, T. & SHIMADA, H. 1995. Segregation of the two sub-species of blue whale in the Southern Hemisphere. Reports of the International Whaling Commission 45: 273-283.

LOESCHER, B.M., DE BAR, H.J.W., DE JONG, J.T.M., VETH, C. & DEHAIRS, F. 1997. The distribution of Fe in the Antarctic Circumpolar Current. Deep Sea Research 44(1-2): 143-187.

MACKINTOSH, N.A. 1942. The southern stocks of whalebone whales. Discovery Reports 22: 197-300.

1965. The stocks of whales. (Fishing News Books: London).

1972. Biology of the populations of large whales. Scientific Progress 60: 449-464.

MIZROCH, S.A. 1984. The development of Balaenopterid whaling in the Antarctic. Cetus 5(2): 6-10.

MONTGOMERY, D.C. 1984. Design and analysis of experiments. (Wiley: New York).

MONTÚ, M., GLOEDEN, I.M., RESGALLA Jr, C. & LOUREIRO FERNANDES, L.F. 1994. Krill populations in the Bransfield Strait and neighbouring areas during the summers of 1983, 1984, 1985 and 1987. Nauplius 2: 107-121.

MONTÚ, M., GLOEDEN, I.M. & MANTOVANELLI, A. 1995. Comunidades zooplanctonicas epi-pelagicas de la region del Estrecho de Bransfield (Antártida) y sus relaciones tróficas. Atlântica 17: 73-93.

SECCHI, E.R., DALLA ROSA, L. & CORTESÃO, J.C. 1999. Whales in Antarctic waters: historical and scientific issues. Whale World 1: 8.

SIEGEL, V. & LOEB, V. 1995. Recruitment of Antarctic krill *Euphausia superba* and possible causes for its variability. Marine Ecology Progress Series 123: 45-56.

STONE, G.S. & HAMNER, W.M. 1988. Humpback whales *Megaptera novaeangliae* and southern right whales *Eubalaena australis* in Gerlache Strait, Antarctica. Polar Record 24(148): 15-20.

TØNNESSEN, J.N. & JOHNSEN, A.O. 1982. The history of modern whaling. (University of California Press: Berkeley).